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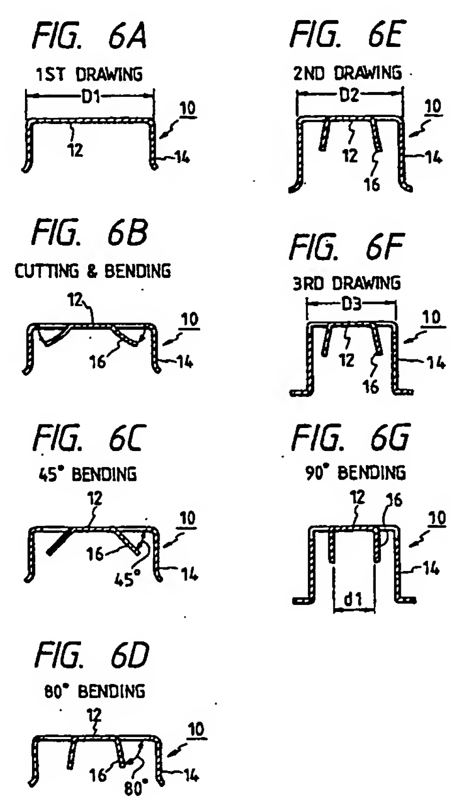
(71) Applicant: CANON SEIKI KABUSHIKI KAISHA
4-19, Nakane 2-chome
Meguro-ku
Tokyo (JP)
Applicant: CANON KABUSHIKI KAISHA
30-2, 3-chome, Shimomaruko,
Ohta-ku
Tokyo (JP)

(72) Inventor: Yamada, Takahisa, c/o Canon Seiki K.K.
4-19, Nakane 2-chome
Meguro-ku, Tokyo (JP)

(74) Representative: Blumbach Weser Bergen Kramer Zwirner Hoffmann Patentanwälte
Radeckestrasse 43
D-81245 München (DE)

(54) Method of manufacturing stator for stepping motor.

(57) In a method of forming a stator for a stepping motor, the present invention first performs the cutting and bending process for forming comb teeth (16) by cutting a flat section (12) of a plate formed with a cylindrical section (14) around the flat portion (12) and bending the comb teeth (16) up to a first angle. Next, in the bending and thickness reducing process, the comb teeth are bent up to a second angle larger than the first angle and the thicknesses of the comb teeth are reduced so as to be uniform. Then, the first drawing process is performed to draw the cylindrical section at least one time. Finally, in the bending process, the comb teeth are bent up to a right angle. Thereby, the occurrence of cambers of the comb teeth and inclinations of comb teeth in the peripheral direction can be inhibited. Also, the squareness of the comb teeth can be improved.



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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of manufacturing a stator for a stepping motor and more particularly to a method of manufacturing a stator for a micro stepping motor whose outer cylindrical section has the diameter of 30 mm or less or a stator for a small size stepping motor having an outer cylindrical section drawn deeply.

Related Background Art

Generally, a stepping motor has, as shown in Fig. 1, a rotor 1, a shaft 2 and stators 3_1, 3_2, 4_1 and 4_2. The stators 3_1, 3_2, 4_1 and 4_2 are each formed with a plurality of magnetic pole teeth (comb teeth) 3a, 3b, 4a or 4b at regular intervals in the peripheral direction. It is preferable to form the length of the comb teeth 3a, 3b, 4a and 4b long in order to increase the effective magnetic flux generated by the excitation of excitation coils 5a and 5b. However, when the comb teeth are formed by blanking simply a center of a single frame plate as conventional, the length of the comb teeth becomes less than half a blanking diameter, so that there is a limitation to obtain large effective magnetic flux. Although Japanese Patent Publication No. 57-211964 discloses a method for solving the above problem, study was made to investigate a further problem upon manufacturing and a method was proposed in a United States Patent Application filed on March, 1, 1994.

However , when the stepping motor is formed to be a micromotor or the outer cylindrical section of the stepping motor is drawn further deeply, above methods are not conducted much, since the outer cylindrical section is shaped so as to be drawn deeply as shown in Figs. 3 to 5. Such a method wherein the cylindrical section is drawn deeply has been proposed in Japanese Patent Publication No. 3-53854.

In this method, as shown by a cross section in Fig. 12A, first, a frame plate 10 is subjected to a drawing process to form a cylindrical section 14 on the outer periphery of a flat section 12 such that the diameter of the flat section 12 becomes D_1. Next, as shown in Fig. 12B, a plurality of comb teeth 16 are cut from the flat section 12 and raised from the flat section 12 at a right angle such that the inside diameter of a concentric circle drawn by the root portions of the comb teeth becomes d_1 and tips of the comb teeth are located close to the outer periphery of the flat portion 12. Next, as shown in Fig. 12C, the cylindrical section 14 is further subjected to a drawing process to make the diameter of the flat section 12 becomes D_2. Finally, as shown in Fig. 12D, the cylindrical section 14 is subjected to a final drawing process to make the diameter of the flat section 12 be D_3 and simultaneously the lower portion of the cylindrical section 14 is bent at a right angle thereby to complete a stator. According to this method, it is possible to make the length of the comb teeth equal to or more than half the value obtained by subtracting the inside dimaeter d_1 of the concentric circle of the comb teeth from the diameter D_3 of the flat portion 12.

However, there are following problems in the above conventional method.

(1) The cutting and raising process is performed such that while the plate is supported by a die from under, a punch is lowered to punch the plate to form the comb teeth and the punch is further lowered until the comb teeth are brought into contact with the peripheral surface of the die to be raised at a right angle. Also, the punch is formed such that it is first brought into contact with a portion of the flat section 12 closer to the cylindrical section 14 and thereafter brought into contact with gradually inner portions of the flat portion 12. Therefore, the force applied to the comb teeth during the cutting and raising process is shifted gradually from the tips of the comb teeth to the root portions thereof. As a result, distortions occur in the comb teeth. Then, after the cutting and raising process, cambers are produced on the comb teeth 16 as indicated by the broken line in Fig. 13 differently from an ideally straight shape as indicated by the solid line in Fig. 13. The occurrence of the cambers causes the power of a motor to be lowered. Especially, when there are variations of shapes of the cambers of the comb teeth, the power of the motor is further lowered.

(2) Also, in the cutting and raising process, if there is a problem regarding the intensity of the die when the cutting and raising of all the comb teeth are performed at a time, the cutting and raising are performed two or three times. In this case, after the first cutting and raising process, spaces are formed in the flat portion, where some comb teeth are cut and raised. Then, in the second cutting and raising process, a force (in the peripheral direction) directed to the spaces is generated, which causes comb teeth for the second cutting and raising process to be distorted in the peripheral direction as indicated by the broken line in Fig. 14 differently from the ideal shape as indicated by the solid line. That is, the inclinations of the comb teeth occur in the peripheral direction. When the resultant stator constitutes a stepping motor. Such inclinations in the peripheral direction causes variations in calculation of step angles, resulting in

the decrease of the positioning accuracy.

(3). Also, although a surface treated steel sheet is utilized as the material of the plate 10, there are variations in thickness of the surface treated steel sheet due to the rolling characteristics thereof. For example, usually, there are about 4% maximum difference of the variations in thickness in the width and rolling directions (Fig. 15). When such a plate with variations in thickness is subjected to the cutting and raising process to form the comb teeth, the squareness or right angle accuracy of the cutting and raising is lowered, reducing the power of the motor together with the cambers of the comb teeth.

(4) When the drawing process is conducted after the cutting and raising process, a force is applied to the raised comb teeth during the drawing process, which causes the comb teeth to be distorted in the radius or peripheral direction.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a method of manufacturing a stator for a stepping motor in which the above problems occurring during the cutting and raising process are solved.

For achieving the above and other objects, a method of manufacturing a stator for a stepping motor according to the present invention, comprises the cutting and bending process for forming a plurality of comb teeth by cutting a flat section of a plate formed with a cylindrical section around the flat section and bending the comb teeth up to a first angle; the bending and thickness reducing process for bending the comb teeth up to a second angle larger than the first angle and reducing the thicknesses of the comb teeth so as to be uniform; the drawing process for drawing the cylindrical section at least one time; and the bending process for bending the comb teeth up to a right angle.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partly broken diagram showing a stepping motor;

Fig. 2 is a partly broken diagram showing a stepping motor formed by drawing the outer cylindrical section of the motor of Fig. 1 deeply;

Fig. 3 is a cross section of the motor in Fig. 2;

Fig. 4 is a partly broken diagram showing a stepping motor by drawing deeply the outer cylindrical section of the motor of Fig. 1 and integrating the coils thereof;

Fig. 5 is a cross section of the motor in Fig. 4;

Figs. 6A to 6G show the processes of manufacturing a stator for a stepping motor according to an embodiment of the present invention;

Fig. 7 is a cross section for explaining the cutting and bending process in Fig. 6B;

Fig. 8 is a cross section for explaining the 45° bending and thickness reducing process in Fig. 6C;

Fig. 9 is a cross section for explaining the 80° bending process in Fig. 6D;

Fig. 10 is a cross section for explaining the second drawing process in Fig. 6E;

Fig. 11 is a cross section for explaining the third drawing process in Fig. 6F;

Figs. 12A to 12D show the processes of forming a conventional stator for a stepping motor;

Fig. 13 is a cross section for explaining a problem of the conventional method of Figs. 12A to 12D;

Fig. 14 is a diagram for explaining distortions of the comb teeth in the peripheral direction occurring in the punching process in Fig. 12B; and

Fig. 15 is a perspective view showing a surface treated steel sheet used as the material for the plate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will be described with reference to the accompanying drawings. First, the whole structure of a stepping motor will be described with reference to Figs. 1 to 5.

In Fig. 1, a rotor 1 of the step motor has a shaft 2 fixed thereto. Two upper and lower stators 3_1, 3_2 are disposed around the rotor 1. Also, two upper and lower stators 4_1, 4_2 are disposed around the rotor 1 under the stators 3_1, 3_2. The stators 3_1, 3_2 are provided on the inner peripheral portions with respective comb teeth 3a, 3b such that the comb teeth 3a are opposite to the comb teeth 3b. Also, the stators 4_1, 4_2 are provided on the inner peripheral portions with respective comb teeth 4a, 4b such that the comb teeth 4a are opposite to the comb teeth 4b. The comb teeth 3a, 3b are formed so as to have the north and south poles alternately in the peripheral direction. The construction of the comb teeth 4a, 4b are the same as that of the comb teeth 3a, 3b. Hollow portions of the stators 3_1, 3_2 and 4_1, 4_2 are provided with bobbins 6a, 6b which have respective excitation coils 5a, 5b wound with many turns. Flanges 7a, 7b are welded to the respective stators 3_1, 4_1 and formed with respective bearings 8a, 8b for supporting the shaft 2 of the rotor 1.

However, when the stepping motor is formed so as to be a micromotor or the drawing of the outer cylindrical section of the stepping motor is made deeper, it is necessary to integrate the stators 3_1 and 4_1 of Fig. 1 into a stator 9 of Figs. 2 to

5. Although thus, the stator 9 of Fig. 2 is formed by integrating the stators of Fig. 1, not only the stators but also the coils are integrated in Fig. 4.

Next, a method of forming the stator 9 will be described. Figs. 6A to 6G show processes of forming the stator 9 for the stepping motor and Figs. 7 to 11 show diagrams for explaining members to be used in the chief processes of forming the stator 9 and the operations of the members.

First, as shown in Fig. 6A, the first drawing process is performed to a plate 10 to form a flat section 12 with the diameter D_1 and a cylindrical section 14 around the outer periphery of the flat section 12. This process is performed in a similar manner to the conventional process.

Next, as shown in Fig. 6B, the cutting and bending process is performed to form comb teeth 16. At this time, the flat section 12 is cut to form comb teeth 16 and the comb teeth are bent only at a predetermined small angle (at an angle in a range of, e.g., 10° to 40°) differently from the conventional cutting and raising process (a flat section is cut to form comb teeth and the comb teeth are raised at a right angle). Therefore, although the whole comb teeth 16 are bent at a time, there is no problem concerning the intensity of a die and no inclination of the comb teeth 16 in the peripheral direction occurs differently from the conventional cutting and raising process wherein the inclination of the comb teeth in the peripheral direction occurs since the comb teeth are divided into a few groups and then bent two times or three times.

Next, as shown in Fig. 6C, the comb teeth 16 are further bent up to, e.g., 45°. Simultaneously, the thickness of the comb teeth 16 are reduced about 10%. In this 45° bending and teeth thickness reducing process, as a punch and die both with respective linear processing surfaces are utilized, the cambers of the comb teeth 16 produced in the previous cutting and bending process as shown in Fig. 6B are corrected to make the comb teeth 16 straight. Also, the thicknesses of the comb teeth 16 are made uniform.

Then, as shown in Fig. 6D, the comb teeth 16 are bent further from about 45° up to about 80°. This 80° bending is for the purpose of making large the width of the upper cylindrical section of a drawing punch to be used in the following second drawing process so as not to cause the lack of the intensity of the drawing punch.

Next, as shown in Fig. 6E, the second drawing process is performed to make the diameter of the flat section 12 be D_2.

Next, as shown in Fig. 6F, the third drawing process is performed to make the diameter of the flat section 12 be D_3 as well as to bend the lower portion of the cylindrical section 14 at a right angle with respect to the cylindrical section 14.

Finally, as shown in Fig. 6G, the 90% bending process is performed to bend the comb teeth 16 up to 90°, i.e., a right angle thereby to make the inside diameter of concentric circles of the comb teeth 16 be d_1. Although the change of the bending angle occurs during the drawing process after the cutting and 90° raising process in the conventional method, it will not occur in this 90° bending process as the 90° bending process is performed finally. Also, as the thicknesses of the respective comb teeth 16 are made uniform in the above-described 45° bending and teeth thickness reducing process, uniform forces are applied to the respective comb teeth 16 in the 90° bending process. As a result, variations of the squareness or right angle accuracy can be reduced.

Next, the members to be used in the chief processes and the operations of the members will be described with reference to Figs. 7 to 11. Fig. 7 is a cross section showing the cutting and bending process corresponding to Fig. 6B. A cutting die 24 is disposed inside the cylindrical section 14 formed in the first drawing process. And, the cutting die 24 is brought into contact with the outer peripheral portion of the flat section 12 of the plate 10 thereby to support the flat section 12. A bending die 22 is disposed in the center of the cutting die 24 so as to support the middle portion of the flat section 12. In this condition, a cutting punch 20 is lowered to cut the flat section 12 to form the comb teeth 16 and simultaneously to bend the comb teeth 16 to a certain degree (at an angle of 10° to 40°). A numeral number 26 represents a stopper.

Fig. 8 is a cross section showing the 45° bending and teeth thickness reducing process corresponding to Fig. 6C. As shown in Fig. 8, while the plate 10 is supported by a supporting die 34 and a bending die 32, a bending punch 30 is lowered to perform the bending and teeth thickness reducing process. As is apparent from Fig. 8, in this process, the bending die 32 with a 45° linear surface and the bending punch 30 with a 45° linear surface are utilized. Therefore, the comb teeth 16 are bent at 45° and become straight. Also, as the respective comb teeth 16 are pressed by the same force, it is possible to reduce the thicknesses of the comb teeth 16 equally about 10%. A numeral number 36 is a stopper.

Fig. 9 is a cross section showing the 80° bending process corresponding to Fig. 6D. As shown in Fig. 9, while the plate 10 is supported by a supporting die 44 and a bending die 42, a bending punch 40 is lowered to perform the 80° bending process. As is apparent from Fig. 9, in this process, the bending die 42 with a 80° linear processing surface and the bending punch 40 with a 80° linear processing surface are utilized. A numeral number 46 represents a stopper. This

process is for the purpose of enabling the insertion of a drawing punch of the following drawing process into the cylindrical section 14 easily by enlarging the distance between the cylindrical section 14 and the comb teeth 16. When e.g., a 60° bending and teeth thickness reducing process is performed other than the 45° bending and teeth thickness reducing process, the distance between the comb teeth 16 and the cylindrical section 14 is enlarged and then the 80° bending process can be omitted.

Fig. 10 is a cross section showing the second drawing process corresponding to Fig. 6E. As shown in Fig. 10, while the plate 10 is supported by a drawing punch 52, a drawing die 50 is operated from above to draw the cylindrical section 14 of the plate 10.

Fig. 11 is a cross section showing the third drawing process corresponding to Fig. 6F. As shown in Fig. 11, while the plate 10 is supported by a drawing punch 62, a drawing die 60 is operated from above to draw the cylindrical section 14 of the plate 10 as well as to bend a lower portion of the cylindrical section 14 at a right angle.

Finally, as not shown, the comb teeth 16 are bent up to 90°, i.e., a right angle. In this 90° bending process, a bending die and a bending punch similar to those shown in Fig. 9 are utilized. However, the bending die has a 90° processing surface perpendicular to the flat section 12 of the plate 10 while the bending punch has a 90° processing surface corresponding to the processing surface of the bending die.

The result of the tests which was carried out to check the effect of the forming method according to the present invention will be described below.

(the results of the tests)

(1) The cambers of the comb teeth in the conventional method were 0.05 mm while those of the comb teeth in the method of the present invention were substantially zero.
(2) The accuracy of the diameter d_1 of concentric circles drawn by the comb teeth was improved.
(3) The inclinations of the comb teeth in the peripheral direction in the conventional method were ± 1° (degree) while those of the comb teeth in the peripheral direction in the method of the present invention were ±10' (minute).
(4) The coaxial degree of the concentric circles drawn by the cylindrical section and the comb teeth in the conventional method was 0.1 mm while that of the concentric circles drawn by the cylindrical section and the comb teeth in the method of the present invention was 0.03 mm.

As described above, according to the present invention, the cutting and bending process and the 45° bending and teeth thickness reducing process are used in addition to the cutting and raising process, so that the cambers of the comb teeth and the inclinations of the comb teeth in the peripheral direction can be reduced and the squareness can be also improved. Further, as the 90° bending process is performed after the drawing processes, the squareness can be improved more preferably.

Claims

1. A method of manufacturing a stator for a stepping motor, comprising:

   a first drawing process for drawing a plate so as to form a flat section and a cylindrical section around an outer periphery of said flat section;

   a cutting and bending process for cutting a plurality of comb teeth from said flat portion and bending said comb teeth;

   a thickness reducing process for reducing thicknesses of said respective comb teeth so as to make the thicknesses of said comb teeth uniform;

   a second drawing process for drawing said cylindrical section after said thickness reducing process such that the diameter of said cylindrical portion becomes smaller; and

   a bending process for bending said comb teeth up to a right angle.

2. A method according to claim 1, wherein said thickness reducing process includes a bending and thickness reducing process for reducing the thicknesses of said respective comb teeth so as to make the thicknesses of said comb teeth uniform as well as bending said comb teeth further.

3. A method according to claim 1, further comprising a third drawing process for drawing said cylindrical section after said second drawing process so as to make the diameter of said cylindrical section much smaller.

4. A method according to claim 2, further comprising a second bending process for further bending said comb teeth bent in said bending and thickness reducing process.

5. A method according to claim 4, wherein said comb teeth are bent up to an angle of 10° to 40° in said cutting and bending process.

6. A method according to claim 4, wherein the thicknesses of said comb teeth are reduced about 10% and said comb teeth are bent up to an angle of about 45° in said bending and thickness reducing process.

7. A method according to claim 4, wherein said comb teeth are bent up to an angle of about 80° in said second bending process.

8. A method of forming a stator for a stepping motor, comprising:

a cutting and bending process for forming a plurality of comb teeth by cutting said comb teeth from a flat section of a plate formed with a cylindrical section around said flat portion and bending said comb teeth up to a first angle;

a bending and thickness reducing process for bending said comb teeth further up to a second angle larger than said first angle and reducing thicknesses of said respective comb teeth so as to make the thicknesses of said comb teeth uniform; and

a drawing process for drawing said cylindrical section at least one time; and

a bending process for further bending said comb teeth up to a right angle.

9. A method according to claim 8, further comprising a bending process for bending said comb teeth up to a third angle larger than the second angle but smaller than a right angle after the bending and thickness reducing process.

FIG. 1

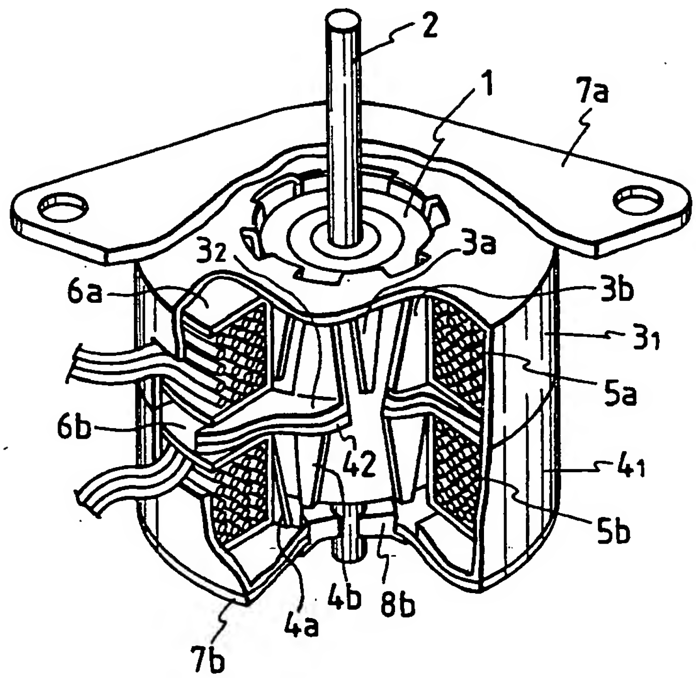


FIG. 2

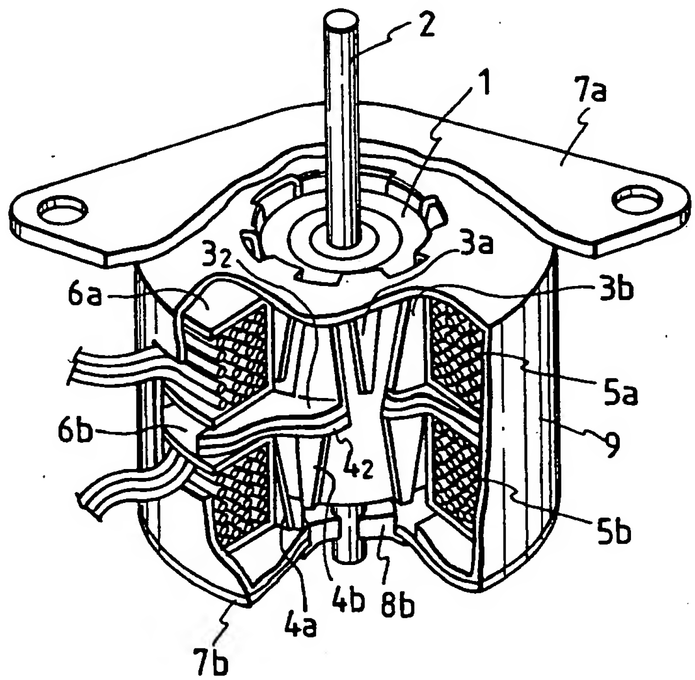

2
1
7a
3_2
3a
6a
3b
5a
6b
9
4_2
5b
4b
8b
4a
7b

FIG. 3

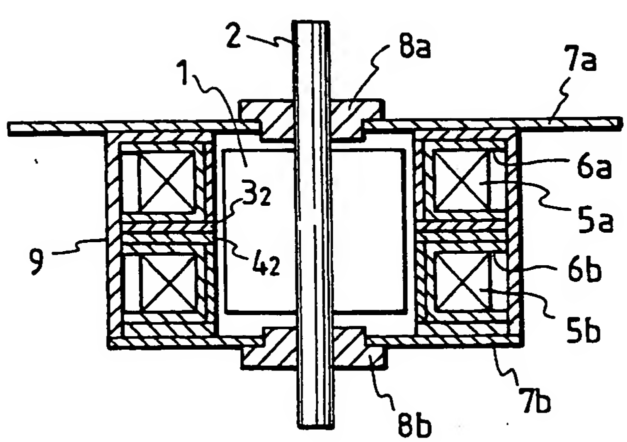

2
8a
7a
1
6a
3_2
5a
9
4_2
6b
5b
7b
8b

FIG. 4

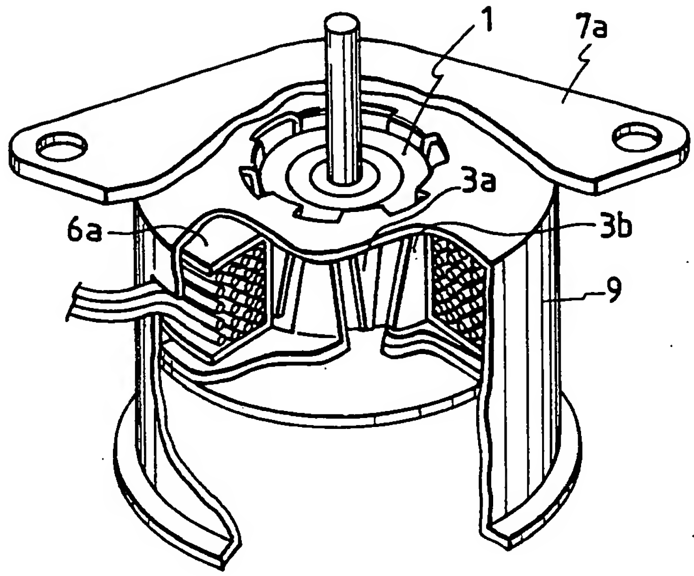


FIG. 5

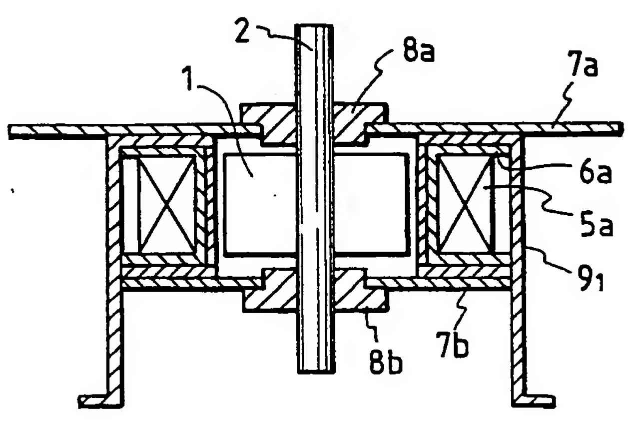


FIG. 6A

1ST DRAWING

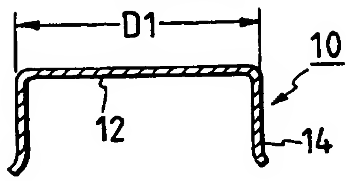


FIG. 6B

CUTTING & BENDING

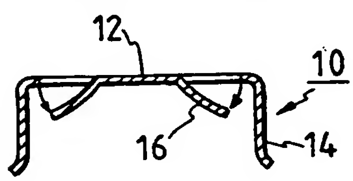


FIG. 6C

45° BENDING

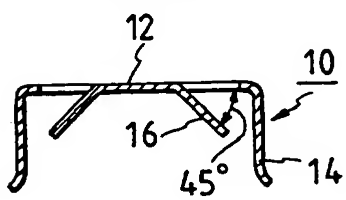


FIG. 6D

80° BENDING

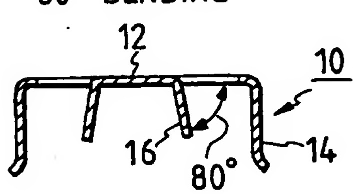


FIG. 6E

2ND DRAWING

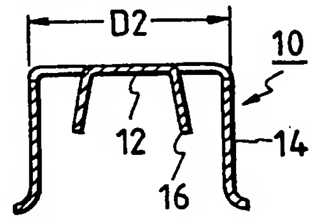


FIG. 6F

3RD DRAWING

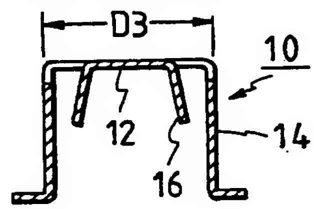


FIG. 6G

90° BENDING

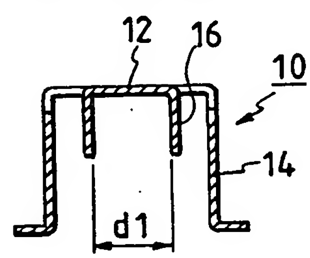


FIG. 7

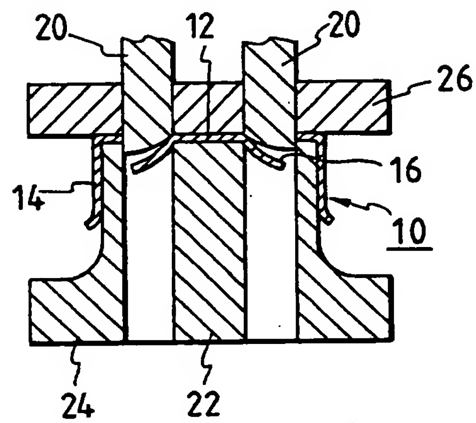


FIG. 8

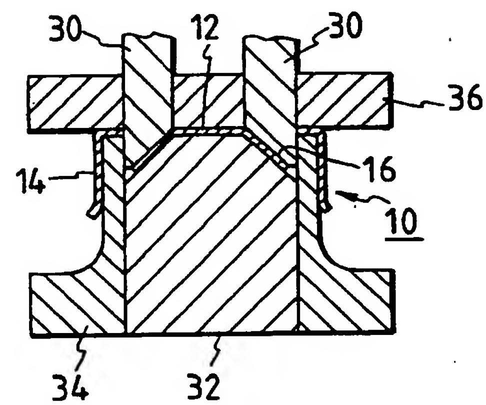


FIG. 9

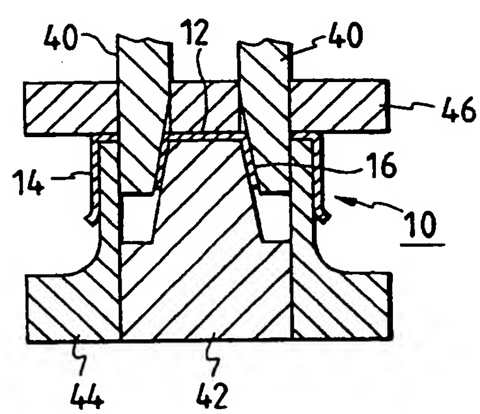


FIG. 10

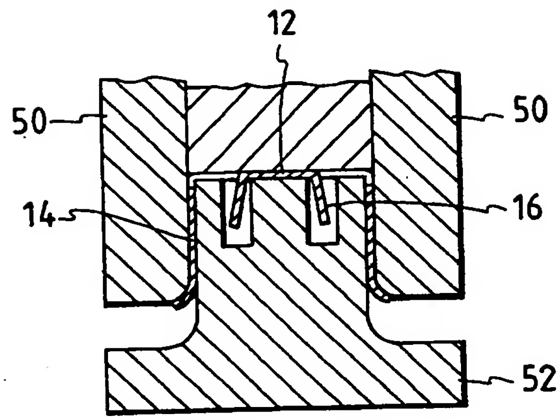


FIG. 11

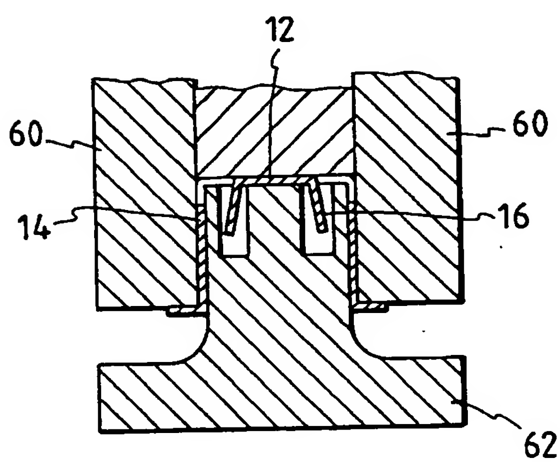


FIG. 12A

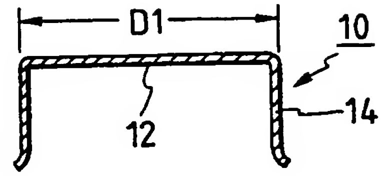


FIG. 12B

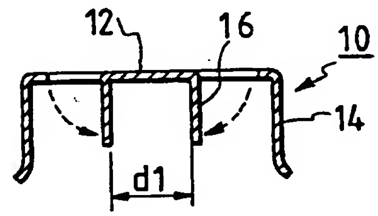


FIG. 12C

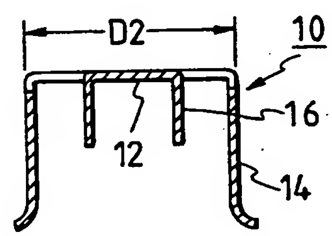


FIG. 12D

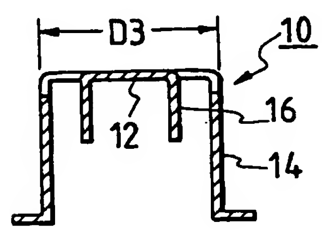


FIG. 13

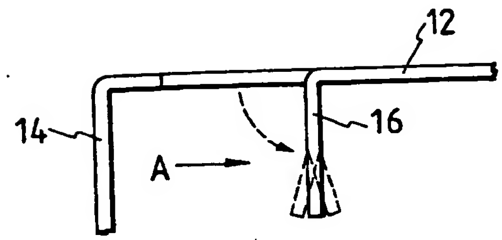


FIG. 14

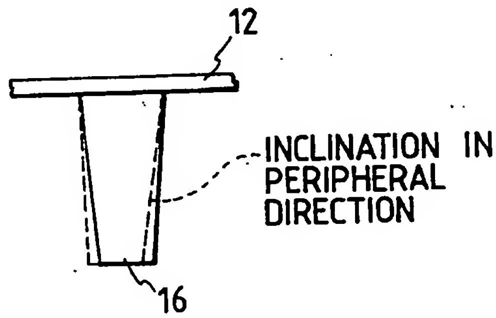
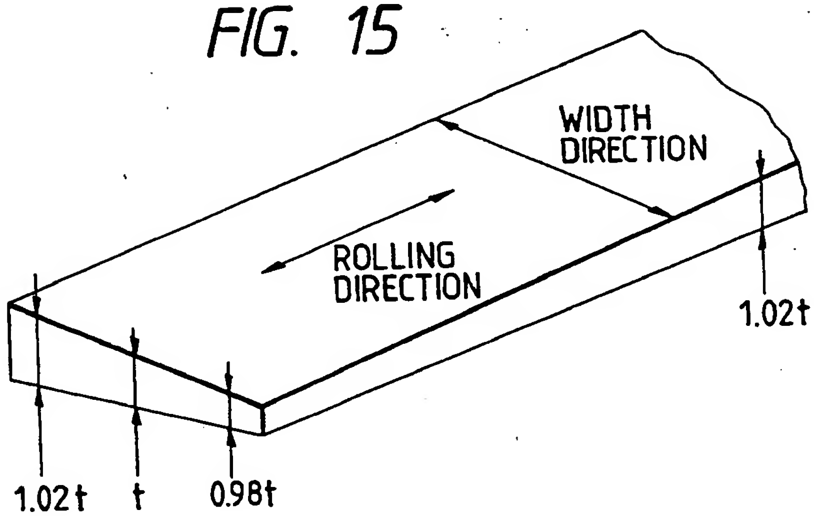


FIG. 15



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 4988

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	US-A-4 418 471 (TORII ET AL.) * column 3, line 9 - column 5, line 54 * ---	1,3,8	H02K15/02
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 107 (E-174) (1252) 11 May 1983 & JP-A-58 029 351 (NIHON SAABO) 21 February 1983 * abstract * ---	1,3,8	
A	GB-A-1 055 201 (COPPERAND LTD) * page 1, line 81 - page 2, line 50; figure 2 * ---	1,3,8	
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 107 (E-174) (1252) 11 May 1983 & JP-A-58 029 350 (NIHON SAABO) 21 February 1983 * abstract * ---	1,8	
A	US-A-1 728 033 (BLAKE R. S. & FABENS A. L.) * page 1, line 84 - line 97; claim 2 * ---	2	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
A	GB-A-2 051 628 (BENTELER-WERKE AG) * page 3, line 57 - line 86; figure 8 * -----	2	H02K B21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 June 1994	Zoukas, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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